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BIOLOGICAL STUDIES OF *HEMICOELUS GIBBICOLLIS* (LECONTE) (COLEOPTERA: ANOBIIDAE), A SERIOUS STRUCTURAL PEST ALONG THE PACIFIC COAST: ADULT AND EGG STAGES

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Abstract.—The anobiid beetle, *Hemicoelus gibbicollis* (LeConte), is among the most serious structure-infesting insect pests along coastal areas of western North America. Adult beetles are difficult to find due to their small size, cryptic coloration, and sedentary behavior. They readily oviposit in crevices of building timbers that eventually may be damaged sufficiently to require replacement. Females can lay in excess of 100 eggs and egg hatch ranges between 85 and 89%. Pheromones play a key role in mate location. These beetles are primarily found in damp crawl spaces and unheated outbuildings.

Key Words.—Insecta, *Hemicoelus gibbicollis,* structure-infesting, adult, egg, pheromone

Structural damage caused by anobiid beetles in the northwestern United States has only recently come to the attention of concerned individuals. Prior to 1970, structural pest inspections were seldom conducted before home sales (T. Whitworth, personal communication), so many infestations went undetected. During the 1980s home prices dramatically increased and inspections became common. Additionally, energy audits conducted by public utilities prior to home insulation programs revealed many serious infestations. As a result of these inspections the extent of beetle damage became much more apparent.

Hemicoelus gibbicollis (LeConte) is the most widespread and damaging anobiid in coastal areas of Washington, Oregon, California, and British Columbia (Suomi 1992). Despite the damage caused by this insect, its biology has remained unrecorded (Furniss & Carolin 1977). A project was begun in 1987 to document the biology and management options of the most damaging anobiids in Washington and adjacent areas. This, and a subsequent paper (Suomi & Akre in press), will describe the life stages, biology, and behavior of *H. gibbicollis.*

Anobiids are difficult to study, and the biologies of only a few species have been documented. The furniture beetle, *Anobium punctatum* (De Geer), is probably the best known wood-infesting anobiid. This insect is the most serious wood-destroying pest throughout England and much of northern Europe, far surpassing termites or any other group of insects (Hickin 1975). Studies conducted by various researchers (Becker 1940; Spiller 1948; Bletchly 1952; Hickin 1953, 1960, 1981; Fisher 1958; Berry 1976) reported most of our knowledge regarding this species. The deathwatch beetle, *Xestobium rufovillosum* (De Geer), caused damage to several wooden landmarks in England and the United States that led Fisher (1937, 1938, 1940, 1941) to document its habits. Moore (1968, 1970), Williams (1977, 1983), and Williams & Mauldin (1974, 1981) studied another structure-infesting anobiid, *Euvrilletta peltata* (Harris), and reported on life cycle, wood species

infested, and management options. Little information on other wood-infesting anobiids exists because of; 1) long life cycles, often in excess of 5 years, 2) difficulty in rearing, and 3) small size and sedentary behavior of the adults.

Materials and Methods

Wood Collection and Storage.—Subflooring and support timbers, primarily Douglas-fir, *Pseudotsuga menziesii* (Mirbel), infested with *H. gibbicollis* larvae were collected from western Washington and Oregon homes and outbuildings during June, July, and August, 1987 to 1991. This wood was transported to the laboratory at Washington State University in sealed containers to maintain moisture content at the higher levels found in coastal areas. A concrete blockhouse (4 m by 1 m by 1 m and covered with 6 mil black polyethylene) was constructed in a shaded location to retain infested timbers until they could be cut into smaller pieces, approximately 30 cm long. These pieces were kept in covered, darkened boxes measuring 38 cm by 28 cm by 15 cm with 1 cm plaster of Paris/charcoal as a substrate to maintain wood moisture between 14 and 17%. Ventilation was provided through two screen-covered holes (35 mm diameter) in the top cover. Wood moisture readings were taken with a Delmhorst Model RC-1C Moisture Meter (Delmhorst Instrument Company, Boonton, New Jersey). An environmental growth chamber was used to maintain conditions at 65 ± 3% RH and 18 ± 1° C. These conditions are commonly found in crawl spaces under buildings in western Washington. Daily observations were made, and upon emergence adult beetles were collected, measured, sexed, and individually stored in gauze-covered glass vials until tested.

Oviposition Chambers.—Bottoms of clear, polystyrene insect diet cups (4 cm tall by 4 cm diameter) were removed and replaced with plastic mesh glued in place. One layer of muslin cloth was attached to a 9 cm by 9 cm by 2 cm wood block top surface to permit oviposition. A male and female beetle were released in each cup which was then inverted and positioned in the center of the block. Test blocks were kept in separate enclosures, and egg counts were made after 30 days. Relative humidity was recorded with a thermohygrometer (Model 8564, Hanna Instrument Company, Chicago, Illinois) and maintained at two levels with saturated salt solutions (Winston & Bates 1960); 75 ± 1% with sodium chloride and 85 ± 1% with potassium chloride (Sigma Chemical Company, St. Louis, Missouri). Relative humidities below 50% and at 65 ± 3% were maintained in laboratory incubators.

Pheromone Tests.—A modified 9 cm plastic petri dish served as the test arena (Suomi et al. 1986). Ovipositors were dissected from ten newly-emerged *H. gibbicollis,* ground in 3 ml methylene chloride, and the extract filtered. Filter paper, 0.5 cm^2, was immersed in this solution and allowed to air dry. Control filter paper squares were immersed in methylene chloride alone. In the arena a filter paper square was placed at each 90 degree interval with test and control squares alternating, for a total of 4 squares. Stegobiol (Fuji Flavor Co., Ltd., Tokyo, Japan), a commercially available attractant for the drugstore beetle, *Stegobium paniceum* (L.), was tested in a similar manner. Pheromone packets were placed at opposing locations within the arena; empty packets served as controls. Three male *H. gibbicollis* were released in the arena center and their movements monitored under red-filtered light. Five replicates were conducted for each material.

Figure 1. Lateral view, male *H. gibbicollis* (×30).

Scanning Electron Microscopy.—The external morphology of male and female *H. gibbicollis* was examined with a scanning electron microscope (SEM; Hitachi S570) at 20 kV. Dried specimens were placed on cardboard points, then mounted on stubs and coated with 30 nm of gold using a Technics Hummer Sputter Coater V. Antennae were removed from 11 beetles (6 males and 5 females), mounted, and individually gold-coated for increased clarity.

Results and Discussion

Adults.—*Hemicoelus gibbicollis* adults are small beetles. Males range in size from 2.5–5.1 mm, (n = 165, $\bar{x}$ = 3.4 mm), and females range from 3.5–6.0 mm (n = 95, $\bar{x}$ = 4.9 mm). They are light to chocolate brown, occasionally red or dark brown. The eyes of the male tend to be larger than those of the female (Figs. 1, 2). A more reliable character for differentiating between sexes is a semicircular depression in the last abdominal sternum, clearly present in males (Figs. 3, 4). *Hemicoelus gibbicollis* can be separated from most anobiid species in the Pacific Northwest by a pointed, thoracic dorsum (Figs. 1, 2). LeConte's (1859) original description is from a specimen collected at Point Reyes, near San Francisco, California.

Emergence.—Adults emerge any time during the day or night. Both sexes chew a circular exit hole approximately 1.5 mm in diameter. Small amounts of frass are evident during this procedure. Eight adult emergences were witnessed, the shortest was 25 min, the longest 18 h. Upon emergence both males and females moved rapidly on the wood surface. If overturned, the beetles used their wings to right themselves, but despite being probed with objects, were not driven to flight. Several authors (Linsley 1943, Mampe 1982) reported that anobiid adults

Figure 2. Lateral view, female *H. gibbicollis* (×45).

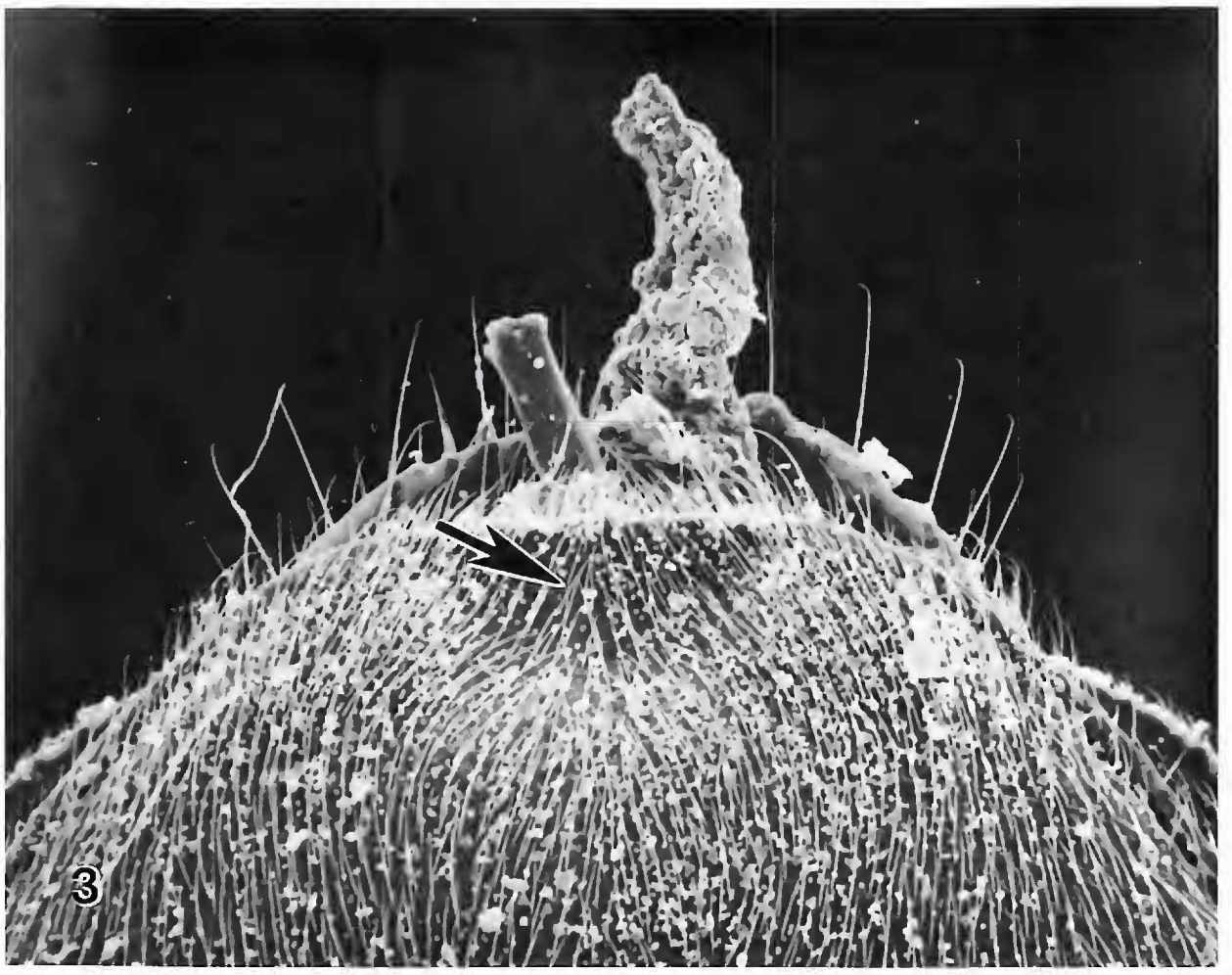

Figure 3. Terminal abdominal sternum, male *H. gibbicollis* (×150).

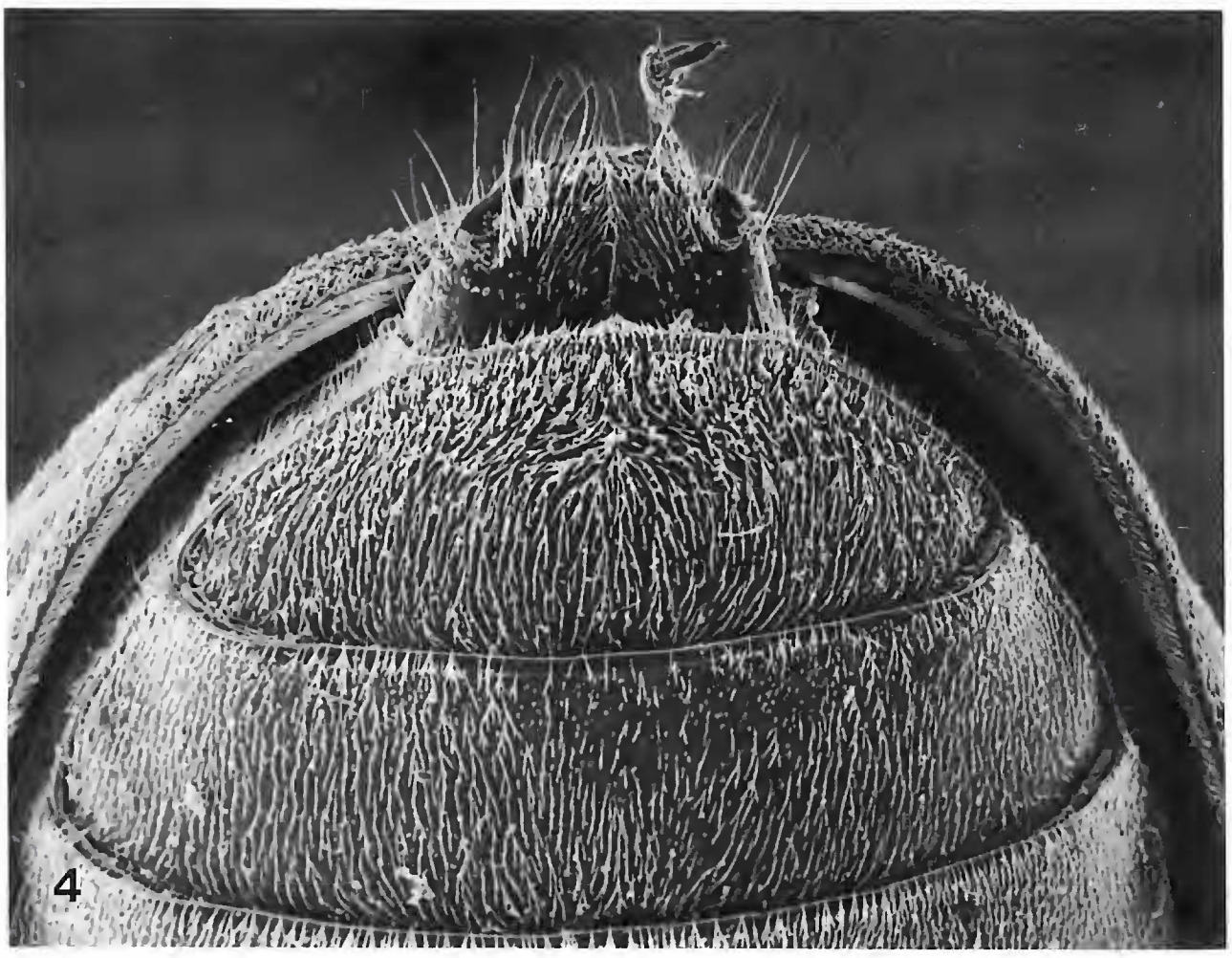

Figure 4. Terminal abdominal sternum, female *H. gibbicollis* (×60).

were attracted to lighted windows and when found in spider webs, one could assess the amount of beetle activity in the structure. During this research only a single male was observed flying toward a florescent light in the laboratory. Keen (1895) stated that *H. gibbicollis* could be captured in flight, but that it was a rare occurrence.

Kelsey et al. (1945) noted a "swarming" phenomenon where 167 male and 3 female *A. punctatum* were found at the same site on a timber. We observed similar behavior on three separate occasions but with smaller numbers of insects (< 20, both sexes). Following this event the wood from which these insects emerged produced very few adult beetles the following year. Pheromones may mediate this coordinated emergence.

In general, anobiid beetles are rarely collected in good numbers (White 1969). Although a building can be seriously infested, *H. gibbicollis* adults are difficult to locate. Both males and females remained motionless on the surface unless engaged in reproductive behavior. Females had a greater tendency to withdraw into emergence holes. When disturbed, males and females feigned death by drawing the appendages close to the body and remained motionless for several minutes. In the laboratory, beetle activity increased between 18:00 and 03:00 h, but adults were seen copulating or ovipositing at various times during the day. After these activities ceased, both males and females returned to a sheltered location, usually an old emergence hole, where they eventually died. Seven male and eight female beetles were closely observed to document longevity (Table 1).

Each year more males than females were collected during laboratory emergences (Table 2). Searching behavior by males may result in increased exposure and greater numbers recorded. Males attempted to copulate immediately upon emer-

Table 1. Longevity of male and female *H. gibbicollis* adults.

Female No.	No. days surviving	Male No.	No. days surviving
1	35	1	17
2	26	2	31
3	30	3	28
4	12	4	27
5	29	5	5
6	19	6	24
7	20	7	13
8	22		
	$\bar{x} = 24.13 \pm 2.59$[a]		$\bar{x} = 20.71 \pm 3.55$[a]

[a] Means ± SEM followed by the same letter do not differ significantly ($P = 0.05$) based on *t*-tests (SAS Institute 1985).

gence, but female beetles required 24–36 h before successful copulation occurred. Upon emergence, females located a crack or depression where they remained prior to mating. Generally, males did not attempt to mate with females found in these locations.

Chemical Communication.—Female *H. gibbicollis* exhibited a calling behavior similar to that observed in other anobiids (Cymorek 1960). The abdomen was raised 45 degrees to the substrate, and the ovipositor tip then everted. A female remained in this position for approximately 15 sec, then returned to a horizontal position for about 30 sec. This behavior was repeated six to eight times, or until a male appeared. A male within 20 cm of the female immediately responded and approached, antennated her head area for 3–4 sec, circled, and mounted from behind. The male then rotated 180 degrees and both beetles remained motionless. Nine observed matings took place under either fluorescent or red-filtered light. Duration of the copulatory period averaged 65.4 min (range = 44–133 min).

In petri dish arenas ($n = 5$ replicates), male *H. gibbicollis* were immediately attracted to filter paper treated with female ovipositor extract. Males antennated the paper 3–4 sec, then remained motionless adjacent to the paper. After 10–15 min, the males moved to the periphery of the arena and ceased movement. On one occasion a male that contacted treated filter paper was pursued by another in an attempt at copulation. This continued for several minutes until the pursuing male lost interest. Beetles did not respond to filter paper controls.

Table 2. Number of male and female *H. gibbicollis* adults emerged from samples during 1987–1991, eastern Washington.

Year	No. males	No. females
1987	70	65
1988	91	86
1989	132	85
1990	186	108
1991	53	52
	$\bar{x} = 106.40 \pm 23.88$[a]	$\bar{x} = 79.20 \pm 9.62$[a]

[a] Means ± SEM followed by the same letter do not differ significantly ($P = 0.05$) based on *t*-tests (SAS Institute 1985).

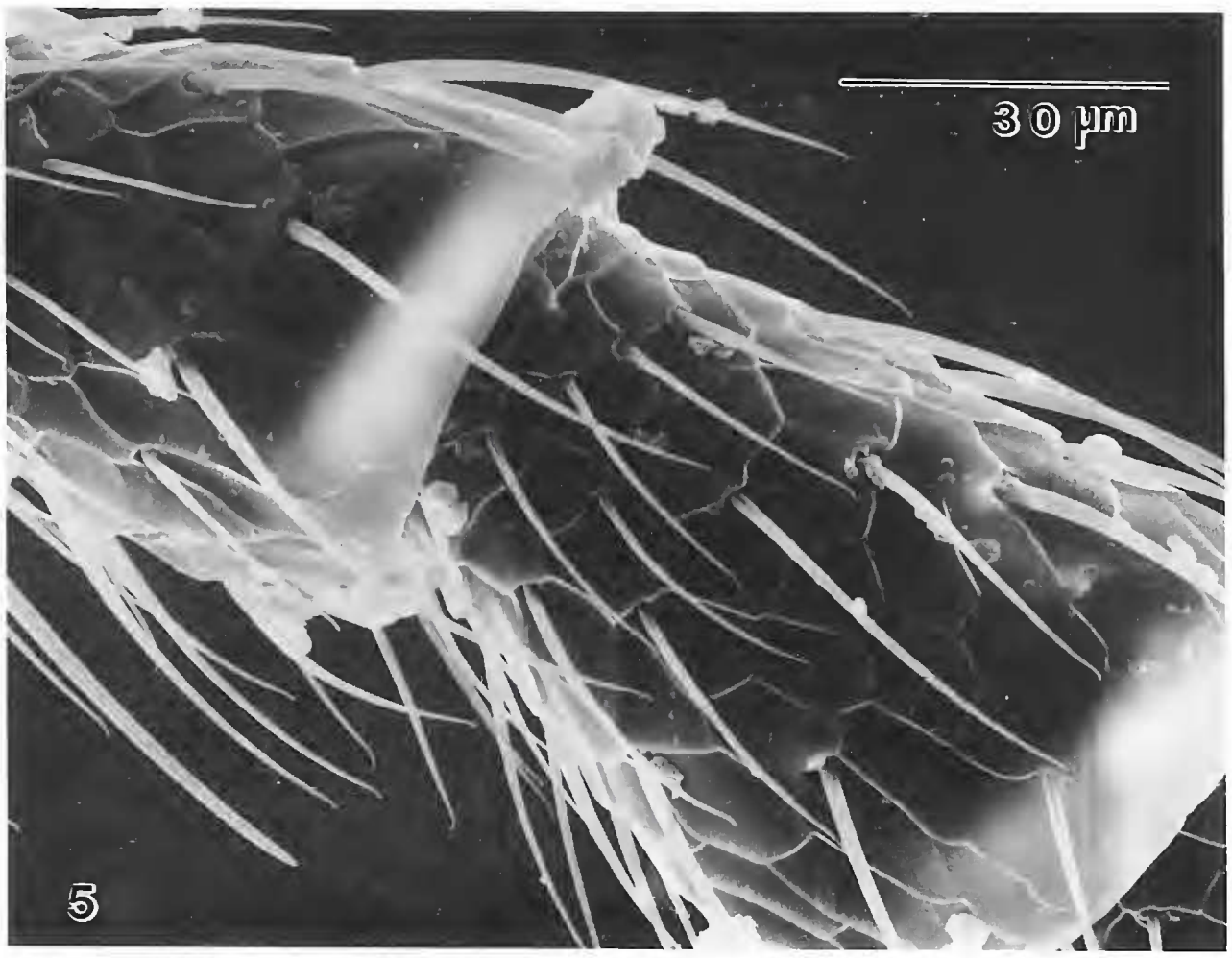

Figure 5. *Hemicoelus gibbicollis* antennal segments 5 and 6 (×1000).

Observations were made of six male and five female *H. gibbicollis* adult antennae to determine if sensory structures were present for sex pheromone reception. Unlike most species that use attractant pheromones (Payne 1974), there is no marked sexual dimorphism of antennal size or shape in this species. All antennal segments of males and females (Fig. 5) are covered with hairs which may be sensory in nature, but these are not thought to be pheromone receptors (Chapman 1982). In species using chemicals as sex attractants, one type of sensory device, the sensilla trichodea, is responsible for sex pheromone perception. These sense receptors were found in greater numbers on male antennae. A presumed olfactory sensillum (Figs. 6, 7) is present which is similar to those seen in the bedbug, *Cimex lectularius* L. (Levinson et al. 1974). Male beetles had, on average, twice as many of these structures on antennal segments 9–11 than did females. Numbers of sensillae were relatively low (approximately 12 in males) which may indicate that large amounts of pheromone are released by the female.

In studies conducted on insects relying on chemoreceptors to detect sex pheromones, openings or pores in the integument were often found in large numbers (Steinbrecht 1987). These pores are thought to allow passage of odor molecules while preventing water loss (Fig. 8). Male *H. gibbicollis* beetles had approximately 50% more of these pores on antennal segments 9–11 than were present on female antennae.

A sex pheromone, stegobiol, has been isolated from *S. paniceum* and is available for use in pheromone traps (Fuji Traps, Tama Trading Co., Ltd., Tokyo, Japan). This compound was discovered (White & Birch 1987) to be structurally identical to the mating pheromone produced by female *A. punctatum.* In laboratory arenas

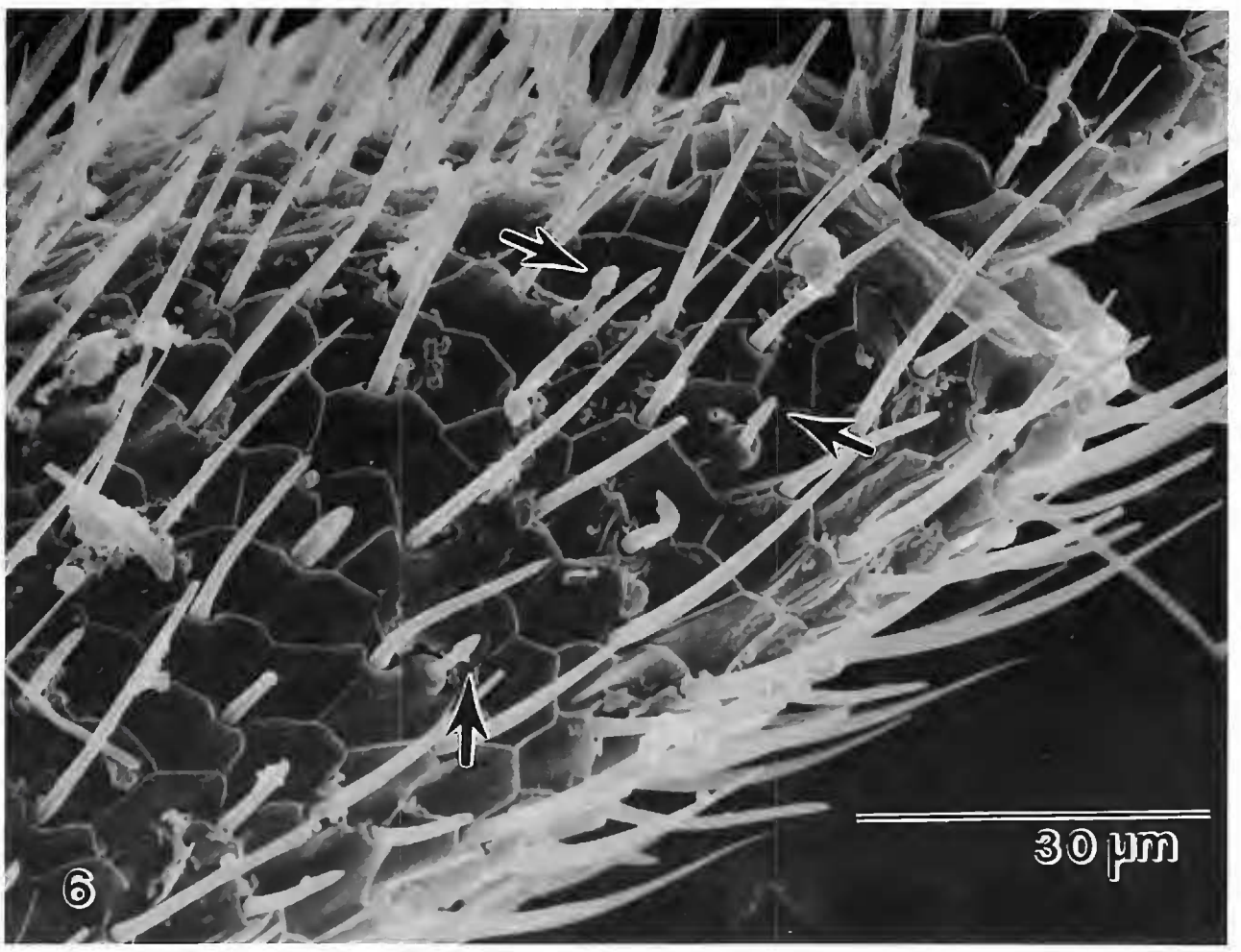

Figure 6. Male *H. gibbicollis* antennal segment 10; note presumed sensilla (×1000).

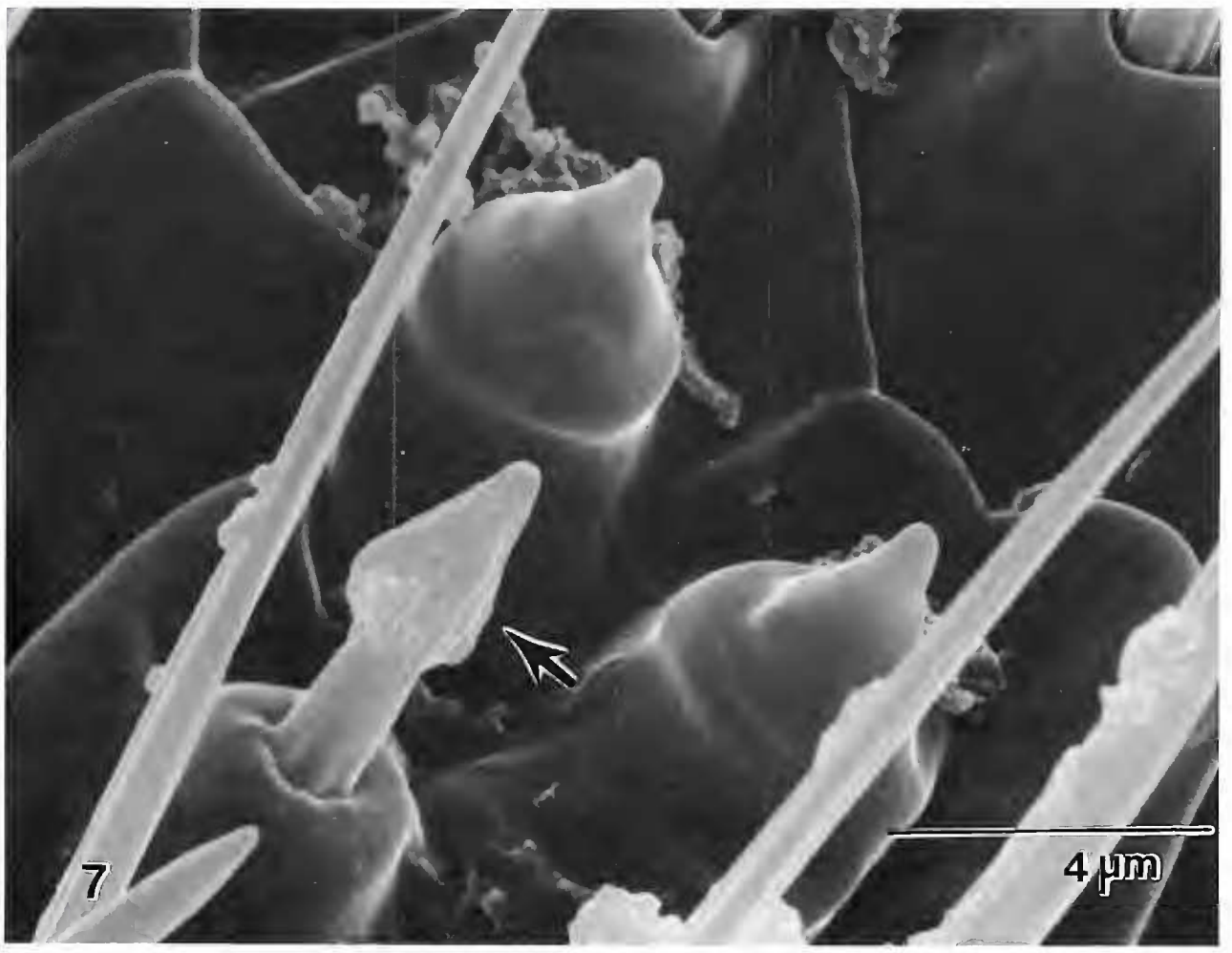

Figure 7. Presumed olfactory sensillum of *H. gibbicollis* (×7000).

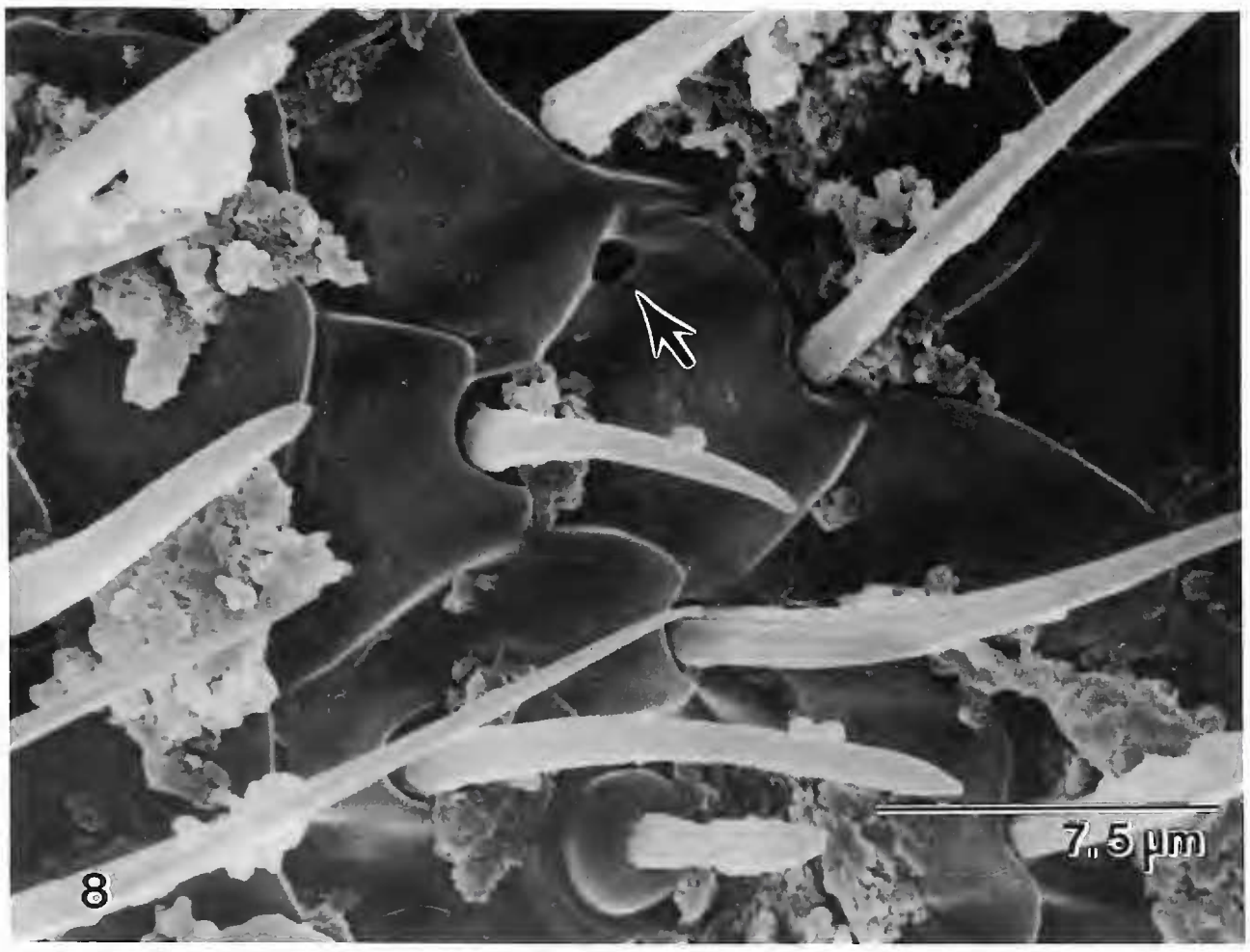

Figure 8. Presumed integumentary pheromone receptor pore; *H. gibbicollis* male antennal segment 11 (×4000).

and field trials stegobiol was ineffective as an attractant for *H. gibbicollis* males. The authors stated that stegobiol isomerizes over time and becomes inhibitory to *S. paniceum*. Within laboratory arenas, male *H. gibbicollis* rapidly moved away from the material when placed near it, possibly due to isomerization of the compound.

Oviposition.—After mating, females located sheltered sites, such as cracks in wood or old exit holes, and remained motionless for 18–36 h. On four separate occasions males mated with three different females. Females were, on three occasions, observed to mate after they had initially oviposited. Few eggs were produced after these second matings (range = 3–8, $\bar{x} = 6$). Females laid eggs singly or in clusters of >100 in cracks or the end grain of the wood. Rarely were eggs laid in old exit holes. Kelsey (1946) and Bletchly (1952) used muslin to encourage oviposition of *A. punctatum* with good results. Thus, on smooth wood surfaces in laboratory tests, muslin cloth was used to stimulate oviposition. In 1990 and again in 1991, 14 females were permitted to oviposit on this surface. Eggs produced per female ranged from 0 to 202, $\bar{x} = 33.9$ per female. These numbers are similar to those reported by Spiller (1964) for *A. punctatum* (range = 0–123, $\bar{x} = 54.8$ per female). In several instances no eggs were produced which may have resulted from female beetles ovipositing prior to capture (Bletchly 1952). Other oviposition studies conducted in 1989 and 1990 resulted in a smaller number of eggs produced per female (Table 3).

A female extruded her ovipositor for 3–4 sec before an egg became visible. Five to 10 sec elapsed for each egg to be laid. While moving through the oviduct anobiid eggs are coated with symbiotic yeasts which supply the larvae with nu-

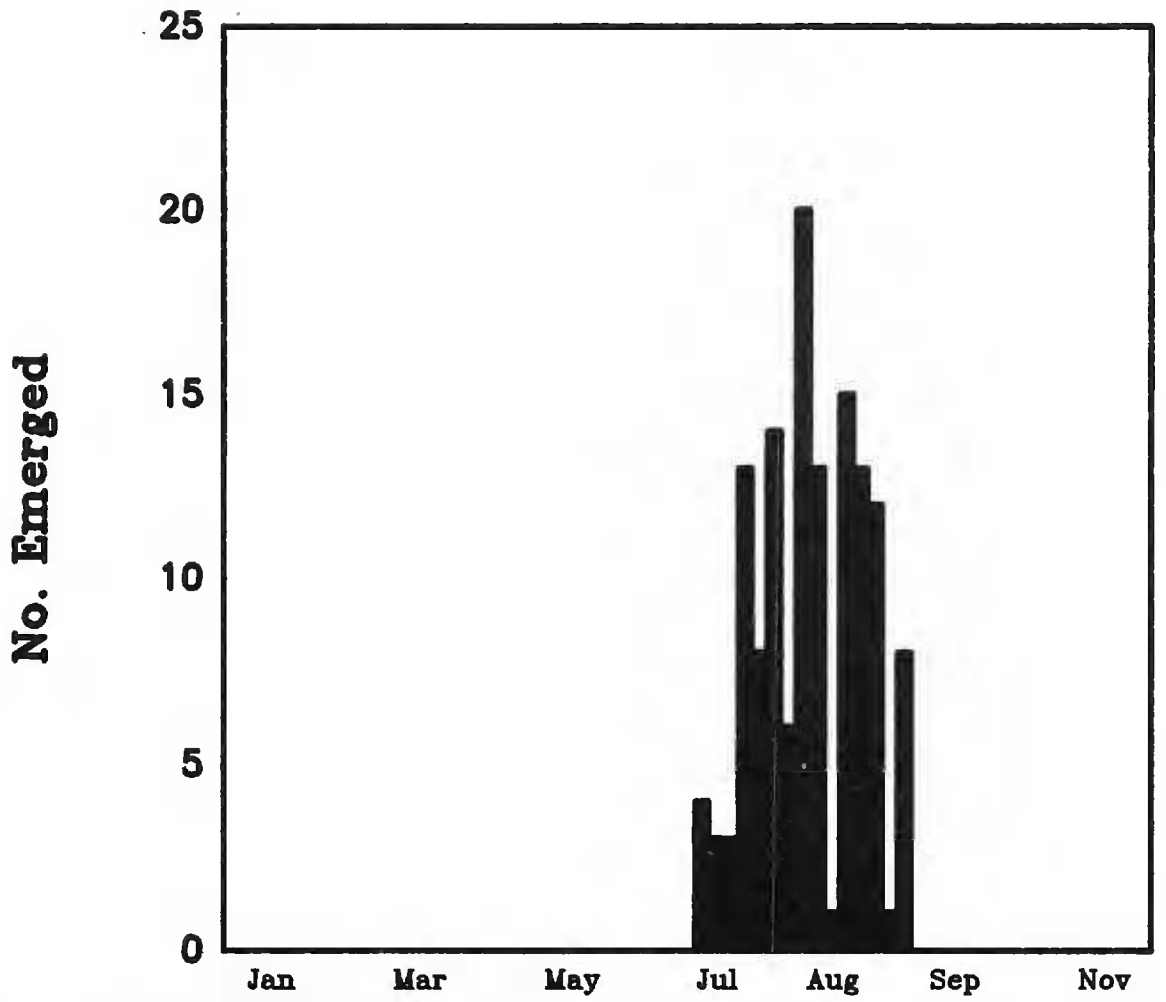

Figure 9. Adult *H. gibbicollis* emergence; e. Washington, 1987.

trients and amino acids (Jurzitza 1979). An adhesive material is produced by the colleterial glands of the female which adheres eggs to the substrate.

Eggs.—Hemicoelus gibbicollis eggs are approximately 0.5 mm long, creamy white, and tapered. A micropyle is evident at one end of the egg. Eggs are typically laid in cracks and crevices and are often distorted when forced into these restricted sites. Larval morphology did not become apparent until a few days before eclosion. Between 85 and 89% of eggs hatch under laboratory conditions which simulated the crawl space environment found in western Washington homes (Table 3). These conditions support a wood moisture regime between 13 and 19% that creates an environment conducive to anobiid larval development. Eggs required between 2–4 weeks to produce first instars (Suomi 1992). No eggs hatched when the RH was <50% (uncommon in western Washington), and fungal development prevented larval emergence if the RH exceeded 85%. Eggs developed normally between these

Table 3. Eggs produced,[a] percent hatch, and number of days to emergence; field collected *H. gibbicollis*.

Year	Total no. females	Mean no. eggs/ female (range)[b]	Mean no. days to hatch (range)	% hatch
1989	7	18.7 ± 3.9[a] (3–32)	22.1 ± 0.5[a] (11–33)	88.6
1990	8	17.4 ± 6.5[a] (1–50)	16.9 ± 0.3[b] (10–31)	84.9

[a] Adults and eggs were maintained in observation boxes at 65 ± 3% RH and 18 ± 1° C.

[b] Means ± SEM followed by the same letter do not differ significantly ($P = 0.05$) based on t-tests (SAS Institute 1985).

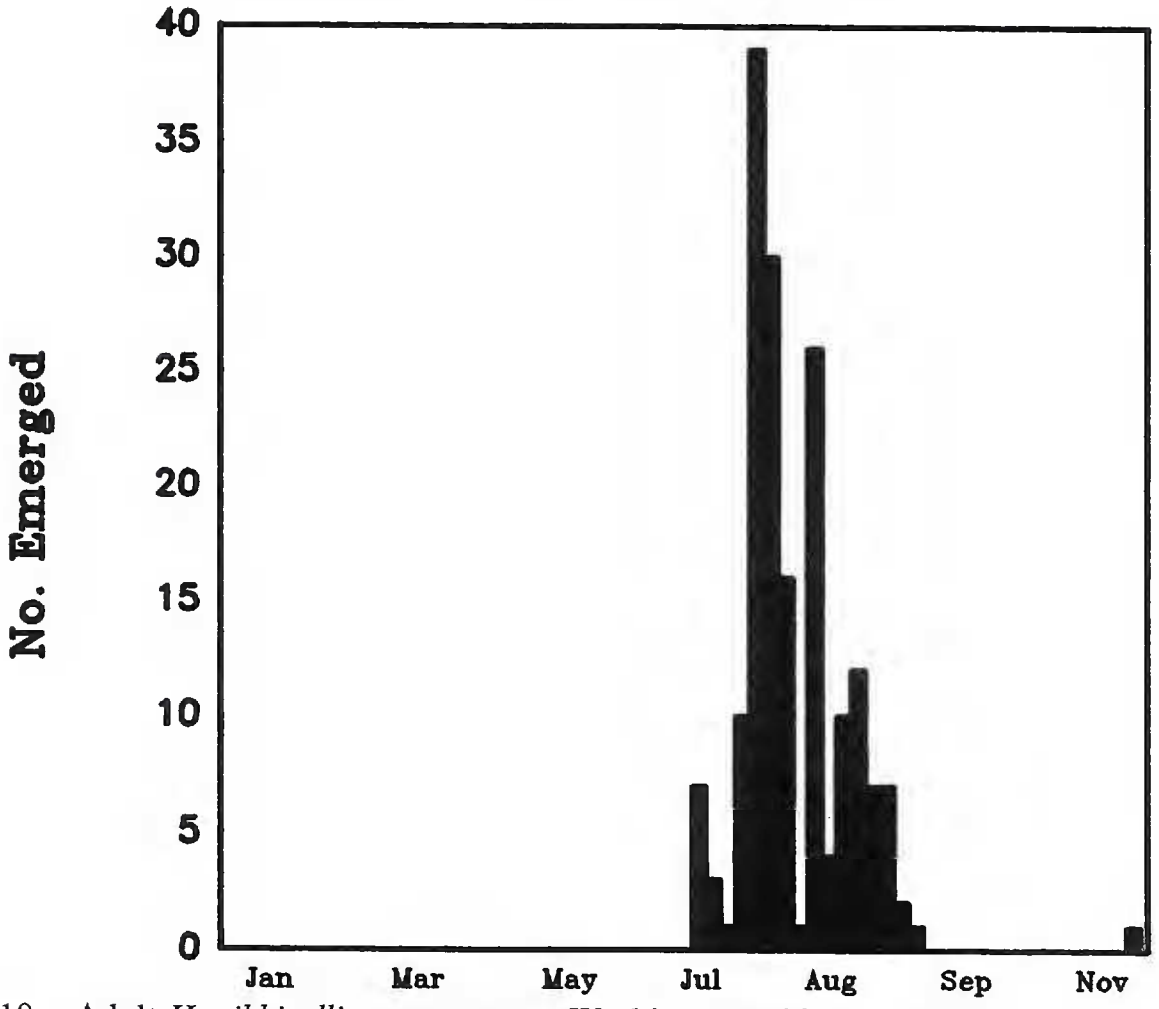

Figure 10. Adult *H. gibbicollis* emergence; e. Washington, 1988.

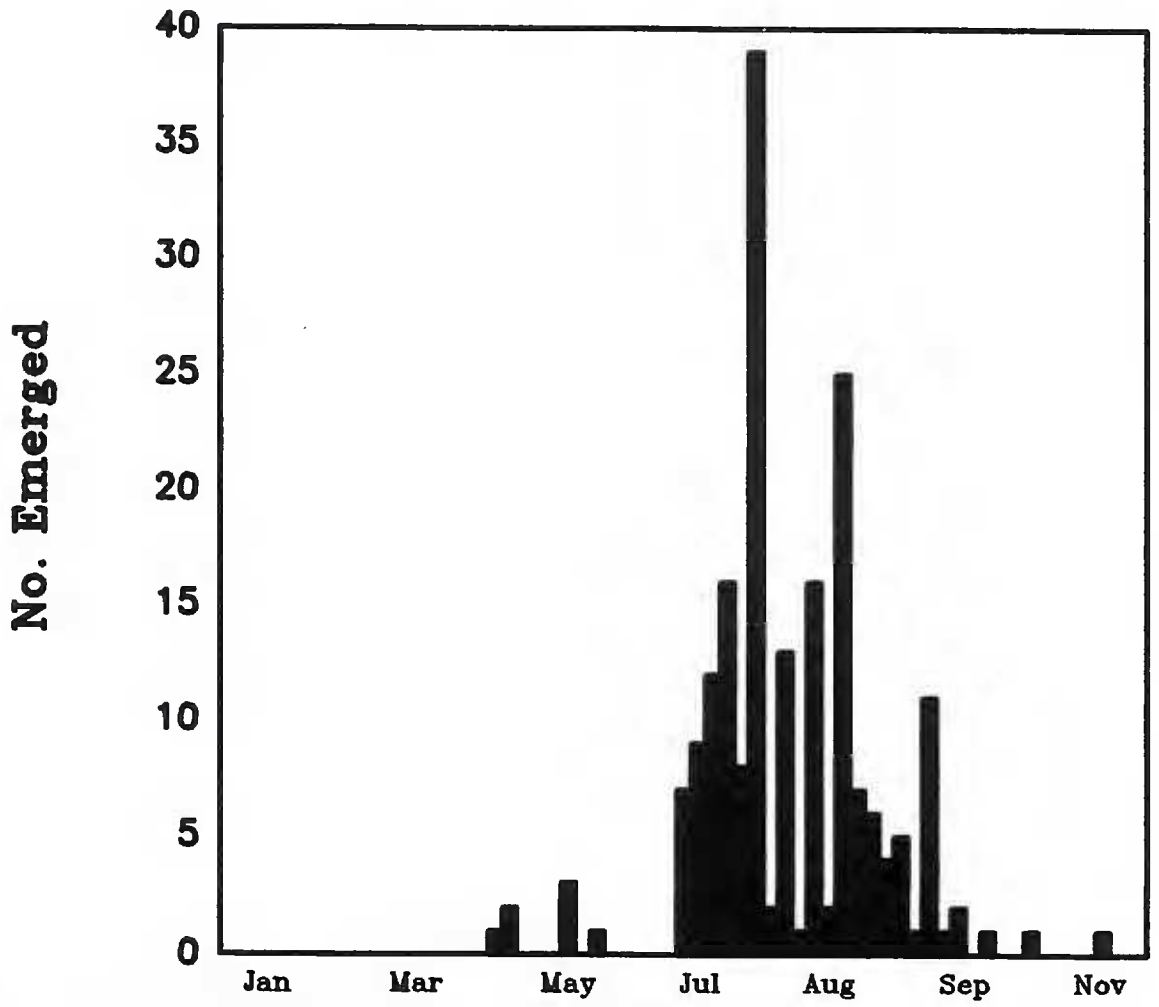

Figure 11. Adult *H. gibbicollis* emergence; e. Washington, 1989.

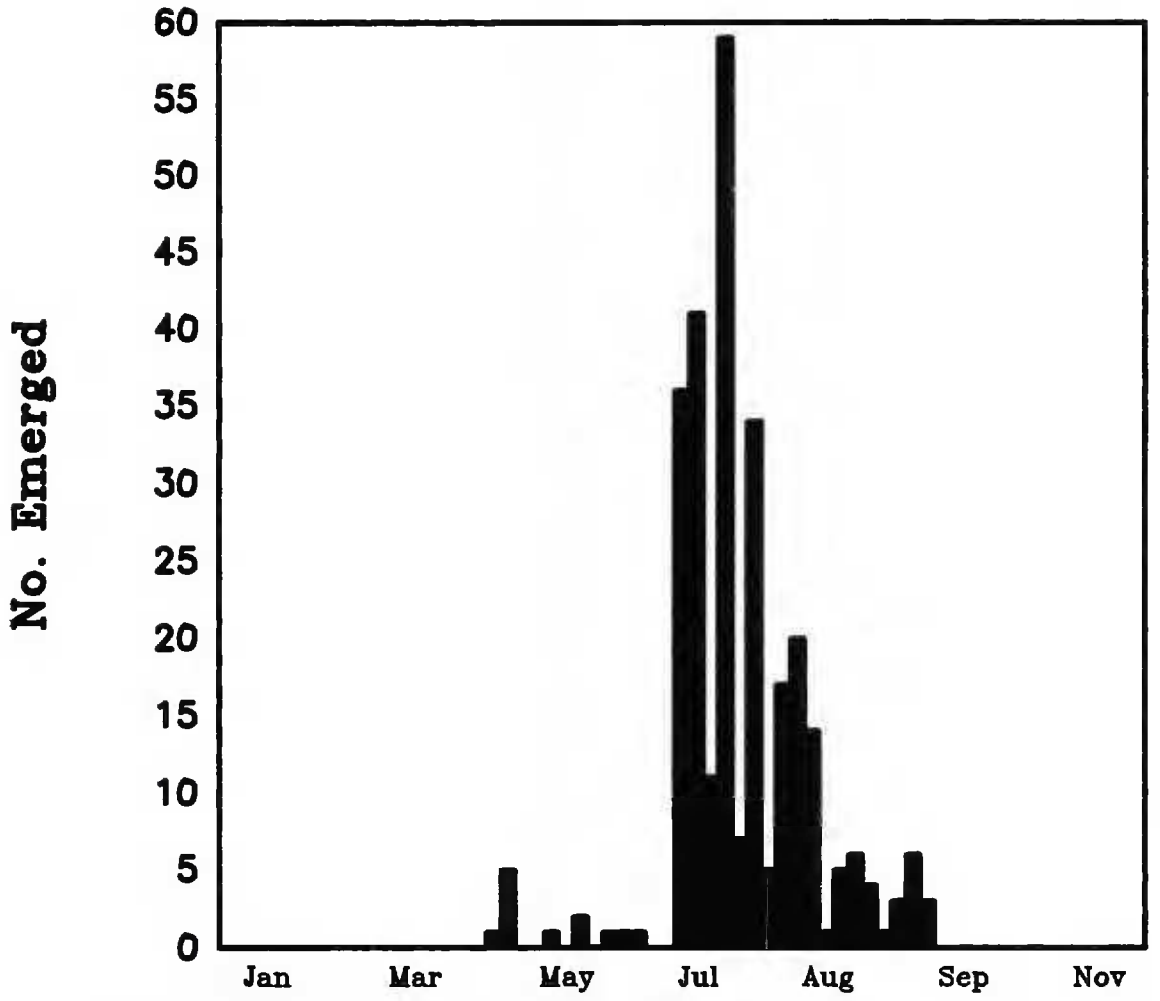

Figure 12. Adult *H. gibbicollis* emergence; e. Washington, 1990.

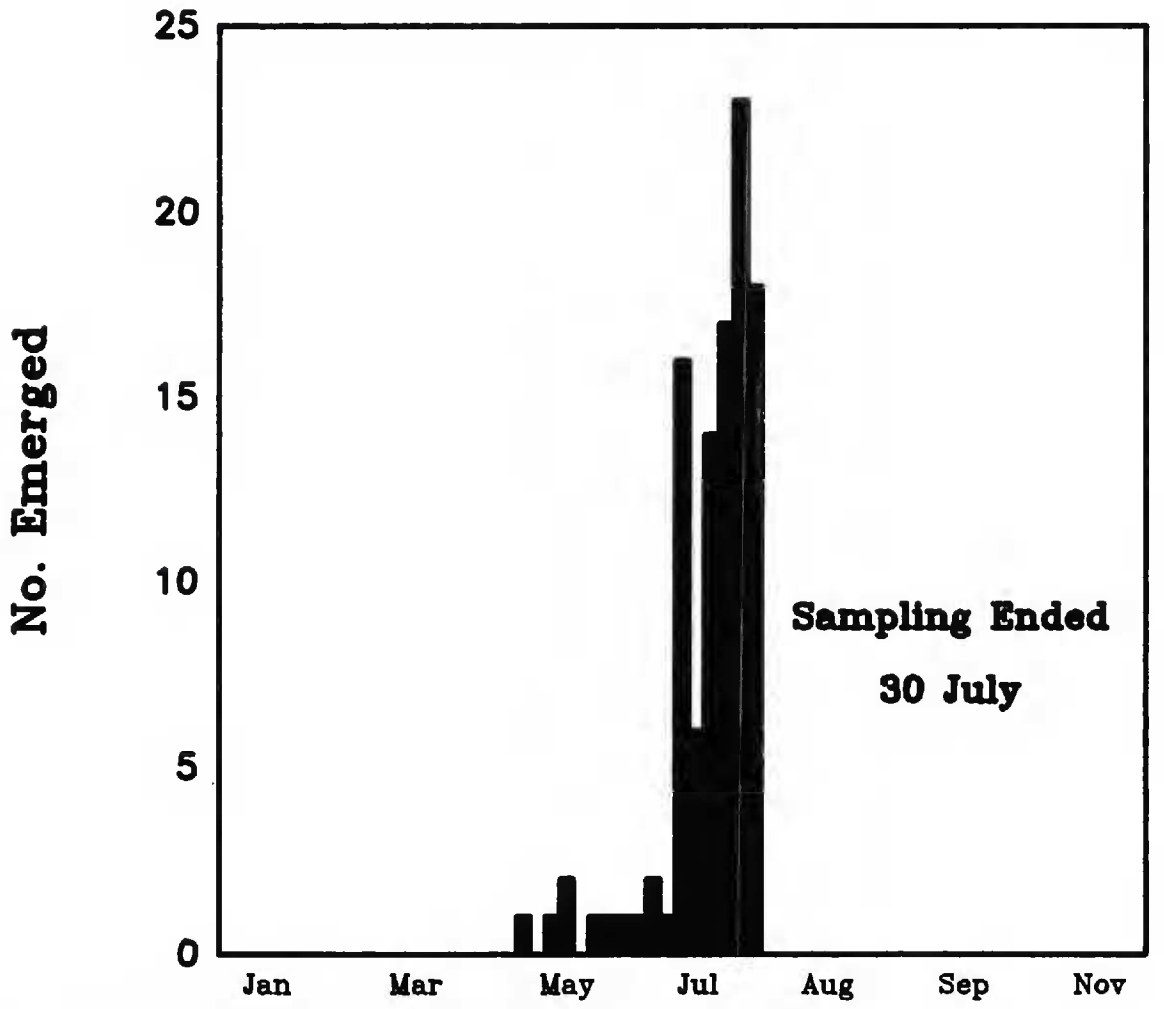

Figure 13. Adult *H. gibbicollis* emergence; e. Washington, 1991.

Figure 14. Distribution of the structure-infesting anobiid, *H. gibbicollis,* western United States.

extremes. The moisture content of recently milled, air-dried lumber found in lumberyards is probably too high for most *H. gibbicollis* eggs to survive.

Adult Activity Period.—Adult beetles are active primarily during summer months in the Pacific Northwest. Laboratory emergence records during 1987–1991 showed that *H. gibbicollis* began emerging in early June and continued until late August. In warmer parts of the range (southern California), emergence may start earlier and continue later in the year. Records acquired from museums and collections along the Pacific Coast (Suomi 1992) showed that most adults were captured during these months. The earliest laboratory collections were on 9 Apr and the

Table 4. Temperature extremes (°C) in emergence containers, eastern Washington.

Year	Maximum	Minimum
1987	35.0	−19.0
1988	34.5	−20.5
1989	39.5	−27.0
1990	36.0	−18.0

latest on 18 Dec (Suomi 1992: appendix 4). These emergences were unusual and probably represent a response to laboratory conditions. The earliest field collections of *H. gibbicollis* were made in Marin County, California on 1 Apr and the latest from 22 Oct in Lincoln County, Oregon. Label data did not always state whether the beetles were alive or dead when collected. Still, only 17 of 183 field collections were made before June or after August (Suomi 1992: appendix 2). Adult beetle emergence in the laboratory during 1987–1991 closely followed this trend, as 869 of 928 collections were made during June, July, and August (Figs. 9–13).

Hemicoelus gibbicollis occurs, for the most part, along the Pacific Coast of western North America where milder climatic conditions prevail (Fig. 14). Higher relative humidity, resulting in greater wood moisture, creates conditions conducive to their survival (Suomi 1992). Temperature extremes do not favor, but will not prevent, emergence of *H. gibbicollis* adults. Infested wood collected in western Washington and stored out-of-doors in eastern Washington produced adult beetles every summer. Temperatures ranged from −27.0° C to 39.5° C within the concrete enclosure (Table 4). Fewer beetles emerged from out-of-door storage than those retained within the laboratory, so these extremes may have had a deleterious effect. Wood moisture is the limiting factor related to larval anobiid survival and although this remained within the optimal range (13–19%), other conditions were quite different from those found along coastal areas. Low relative humidity and low wood moisture found within most inland area buildings may be the major reason for limiting the distribution of *H. gibbicollis*.

Acknowledgment

We greatly appreciate the assistance of the many structural pest control operators in Washington and Oregon who located anobiid-infested structures for this research. Additionally, we would like to thank Chris Davitt at the Washington State University Electron Microscopy Center for assistance with the SEM.

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